Gain Mapping and Response Uniformity Testing of the Hamamatsu R8900 Multianode Photomultiplier Tube and the Burle Planacon Microchannel Plate Photomultiplier Tube for the Picosecond Timing Project

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ABSTRACT

Gain Mapping and Response Uniformity Testing of the Hamamatsu R8900 Multianode Photomultiplier Tube and the Burle Planacon Microchannel Plate Photomultiplier Tube for the Picosecond Timing Project. MELINDA MORANG (University of Chicago, Chicago, IL 60637) KAREN BYRUM (Argonne National Laboratory, Argonne, IL 60439).

Research is currently underway for the development of a microchannel plate photomultiplier tube with picosecond timing capabilities, a property that would be extremely useful in many fields of physics and in radiology. It is important in a research and development study such as this one to fully understand the currently available technology, and the study presented in this paper focuses on characterizing gain and response uniformity in the Hamamatsu R8900-00-M16 multianode photomultiplier tube (R8900) and the Burle Planacon 85011-501 microchannel plate photomultiplier tube (MCPPMT). The tubes were tested using a dark box setup in which a moveable fiber carrying an LED pulse could be directed into each pixel in the tube. The gains for each pixel of ten R8900 tubes and for part of an MCPPMT were calculated, and a horizontal scan in 1mm steps was performed across the breadth of the R8900 and across one quadrant of an MCPPMT. Plots showing the signal output in the horizontal scans showed that the MCPPMT had much greater response uniformity across the tube, but due to time and equipment restraints, these results are only preliminary, and more extensive study of uniformity is necessary, as is study of many other properties of these tubes.

INTRODUCTION

The development of a photomultiplier tube with faster timing would be beneficial to many fields of experimental physics and radiology which make use of time of flight detectors. Thus, recently a collaboration of scientists and engineers from The University of Chicago and Argonne National Laboratory have begun research and development using a microchannel plate photomultiplier tube and readout electronics with the goal of achieving timing on the order of 1 psec [1, 2], which is about two orders of magnitude smaller than that for typical phototubes currently in use [2].

In a research and development project such as this one that aims to enhance existing technology, it is useful and important to analyze the current technology for comparison purposes. In this case, analysis of photomultiplier tubes currently in use should be performed. This analysis should not be limited to the timing properties, however, but should include a complete and thorough characterization of all aspects of the tubes. The current study consists of measurements and comparison of gain and response uniformity of two types of commercially available photomultiplier tubes, the Hamamatsu R8900-00-M16 multianode photomultiplier tube (R8900) (Figure 1) and the Burle Planacon 85011-501 microchannel plate photomultiplier tube (MCPPMT) (Figure 2).

The face of the R8900 is a 24 mm by 24 mm square and contains 16 pixels arranged in a 4x4 grid with pixel center-to-center separation of 6 mm. This tube exhibits many desirable characteristics, but previous studies have indicated that it suffers from a lack of uniformity across the pixels [3].

The MCPPMT is 48 mm by 48 mm and contains 64 pixels arranged in an 8x8 grid that also has pixel center-to-center separation of 6 mm. The design of the tube allows for much greater response uniformity than the R8900 [3, 4]. Current efforts in the development of picosecond timing capabilities focus on modifications and improvements to the technology used in this Burle MCPPMT.

In this study, the gain of each pixel in ten R8900 phototubes was determined. Due to time constraints and lack of equipment, only the gains of the 16 pixels in one quadrant of a single MCPPMT were studied. With this small amount of data, however, some preliminary measurements of the uniformity of response across each tube were conducted and the results analyzed with and without gain corrections.

METHODS

Each phototube was placed in a dark box (See Figure 3) containing a blue LED, a Hamamatsu R580 single anode photomultiplier tube for reference, and a mount for the phototube to be tested. The reference tube and the tube being tested were powered by separate high voltage power supplies. Light from the LED pulsed from an external circuit was guided by way of a fiber optic cable through an externally-controlled graded neutral density filter wheel and into the phototube. The position of the end of the fiber relative to the face of the tube could be determined and adjusted by an externally controlled two-axis stager.

The data acquisition system used a RABBIT electronics crate to record the analog signals produced by the phototubes and convert them to digital signals (ADC counts). For a detailed description of the RABBIT system and the DAQ, see [5, 6].

Before the actual gain mapping, it was necessary to determine the location of the center of each pixel. Pixel 10 was somewhat arbitrarily chosen for the initial horizontal and vertical scans that would determine the precise position of all the pixels. The fiber was moved in one millimeter steps across the estimated position of the pixel center for approximately six millimeters, and data was taken at each step. A ROOT macro written by Robert G. Wagner plotted the number of ADC counts vs. the horizontal or vertical position of the fiber, which exhibited an obvious peak at the center of the pixel. The mean of a Gaussian fit on each of these plots determined the best estimate for center of pixel 10. Because all 16 pixels are six millimeters apart in the grid, the known location of pixel 10 also determined the locations of the centers of all the other pixels. Figure 4 shows a typical vertical scan.

A pedestal run was taken with the LED off, and then a full scan of each pixel center was performed. Data was taken with the LED pulsing in the center of all 16 pixels individually with the tube at both 600V and 650V. Additional data was taken at 575V and 800V for pixels 1-4. Another ROOT macro written by Wagner created a gainmap using the data from these runs. Gains for pixels 1-4 for 575V and 800V were calculated by hand using the formulation below (Wagner's code is based on this formulation as well).

For an individual pixel, the number of ADC counts associated with an LED signal is first pedestal corrected.

NADCsig = NADCtot – NADCped (1)

These numbers are determined by the mean of a Gaussian distribution of ADC counts from multiple trials. The standard deviation of the signals, therefore, must also be taken into account.

$$\sigma ADCsig = \sqrt{(\sigma ADCtot)^2 - (\sigma ADCped)^2} \qquad (2)$$

From this, the number of photoelectrons created by the LED photons is determined by

$$Npe = \left(\frac{NADCsig}{\sigma ADCsig}\right)^2 \qquad (3)$$

The gain, in number of ADC counts, is given by

$$G' = \frac{NADCsig}{Npe} \tag{4}$$

The RABBIT electronics system has a gain conversion of 1.144 fC / ADCcount, which means that at a gain of 10^6, a single photoelectron produces (10^6) x 1.602×10^{-4} fC at the anode. This corresponds to 140 ADCcounts, so

$$G = \frac{G' \times 10^6}{140 ADCcounts} \tag{5}$$

In order to check the uniformity of response across the entire tube, a horizontal scan across the row containing pixels 9, 10, 11, and 12 was performed on R8900 tube ZA1910 at 600V by stepping the LED fiber in 1mm increments and taking data at each point. A ROOT macro was created to sum together the graphs from each of the four pixels of ADC count vs. horizontal position. The macro created an initial plot of the pedestal corrected sum and another additionally corrected by normalizing each signal with respect to the highest gain of the four pixels.

After the characterization of ten R8900 PMTs, the setup was reconfigured for the study of the MCPPMT. The stager motor that moved the fiber from one pixel to another on the face of the plate was too small to reach across this larger tube, so cables were connected in such a way that only one quadrant at a time, a total of 16 pixels, would be read out. Some initial scans of the first quadrant were performed, including a horizontal scan across a single row of four pixels in the first quadrant similar to that done on the R8900.

The same ROOT macro was used to graph ADC count vs. horizontal position for this scan, and a plot of the sum of the signals from four pixels with pedestals subtracted was created, as was another plot that included gain corrections.

RESULTS

Figure 5 shows a good example of a gainmap for one of the R8900 phototubes. The gain in units of 10^5 for each of the 16 pixels is displayed in the center of each box. The number of photoelectrons is also displayed for each pixel. Gainmaps were created for all of the ten R8900 phototubes at both 600V and 650V. All gainmaps are posted online at http://www.hep.anl.gov/morang/Camera.html.

Figure 6 shows a plot of ADC count vs. horizontal position for the R8900 in which the signals from each of four pixels (12, 11, 10, and 9) have been summed and from which pedestals have been subtracted. A gain correction has been applied to the plot in Figure 7. Figure 8 shows a plot similar to Figure 6 but for the MCPPMT. Figure 9 is the gain corrected version.

In each of these plots, approximately 24 mm in x corresponds to the edge of the phototube. For the R8900, 0 mm corresponds to the other edge, while in the MCPPMT, 0 mm is near the center of the tube and the edge of the quadrant. However, because only one quadrant of the MCPPMT was turned on and attached to the DAQ system, 0 mm represents the approximate edge of any data collection in this test.

CONCLUSIONS

Analysis of the gainmaps shows that in the R8900 gain can vary from pixel to pixel by as much as a factor of three. The continuation of this study should include similar gain mapping of all 64 pixels in a comparable number of MCPPMTs.

Figure 6 and Figure 8 show that in both tubes signal decreases when the fiber approaches the outer edge of the tube, which may be expected. Because only one fourth of the channels in the MCPPMT were active, the drop-off in ADC counts on the lower end of the x-axis in Figure 8 most likely does not indicate a lack of uniformity but indicates missing signal from the next pixel in line horizontally. Therefore, while the ADC counts across the R8900 differ by as much as 4500, variation in ADC counts in the MCPPMT may be considered to be less than 1000.

The gain corrections used in Figures 7 and 9 have an unfortunate effect on the data. The rescaling of the R8900 plot decreased the uniformity by more than a factor of three with a difference from maximum to minimum ADC counts of about 17,000. For the MCPPMT, the difference is still less than 1000, although the plot appears less uniform. The peak on the left could simply be the result of overcompensation in the gain correction due to the missing data from the inactive adjacent pixel.

It is unclear why the gain corrections had such a detrimental effect on the R8900 data. Careful review of both the gain correction method and the method of calculating the gain itself is needed.

In order to get a better idea of the behavior of the MCPPMT, more extensive studies on this tube should be performed in which all pixels are active. A two-axis stager with a larger range should be obtained to allow for scanning across the full height and width of the tube.

In the mean time, the preliminary results obtained in this study indicate that the MCPPMT is, as expected, much more uniform than the R8900 multianode PMT.

This study encompasses only a small part of a complete analysis of the R8900 and the MCPPMT. As the initial phases of the picosecond timing project are conducted, studies of these two phototubes should continue. Further investigations should include completing response uniformity comparisons, determining gain stability over time, examining crosstalk between pixels, studying linearity, examining single photoelectron peaks, and testing the actual timing properties of both tubes.

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Figures

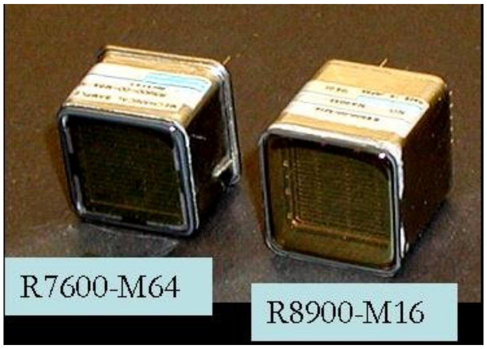

Figure 1. The Hamamatsu R8900-00-M16 multianode photomultiplier tube (right).

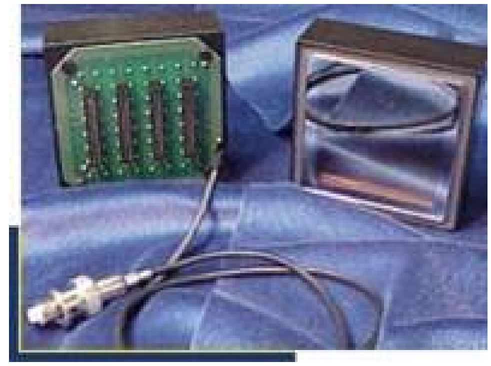

Figure 2. The Burle Planacon 85011-501 microchannel plate photomultiplier tube.

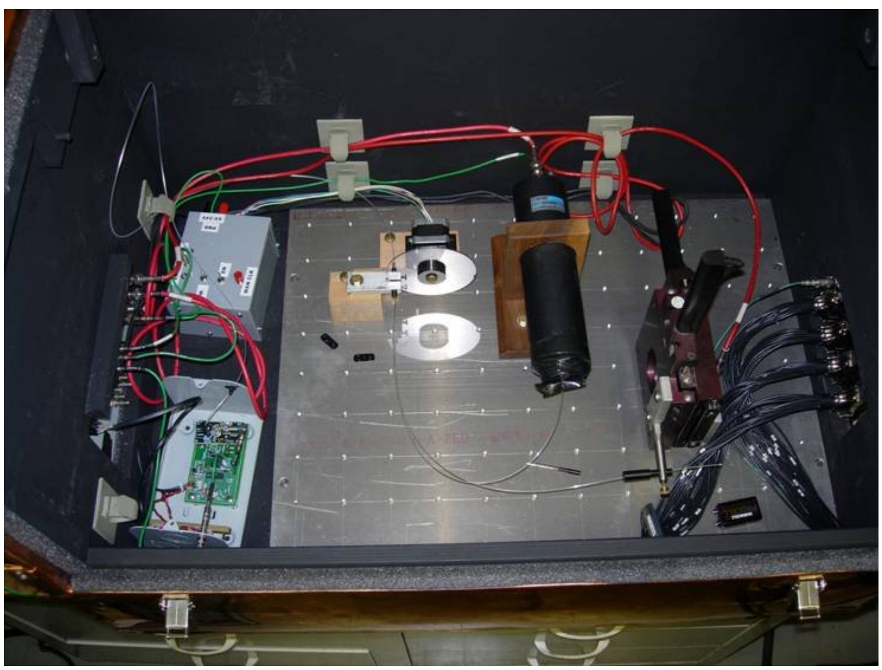

Figure 3. The darkbox setup.

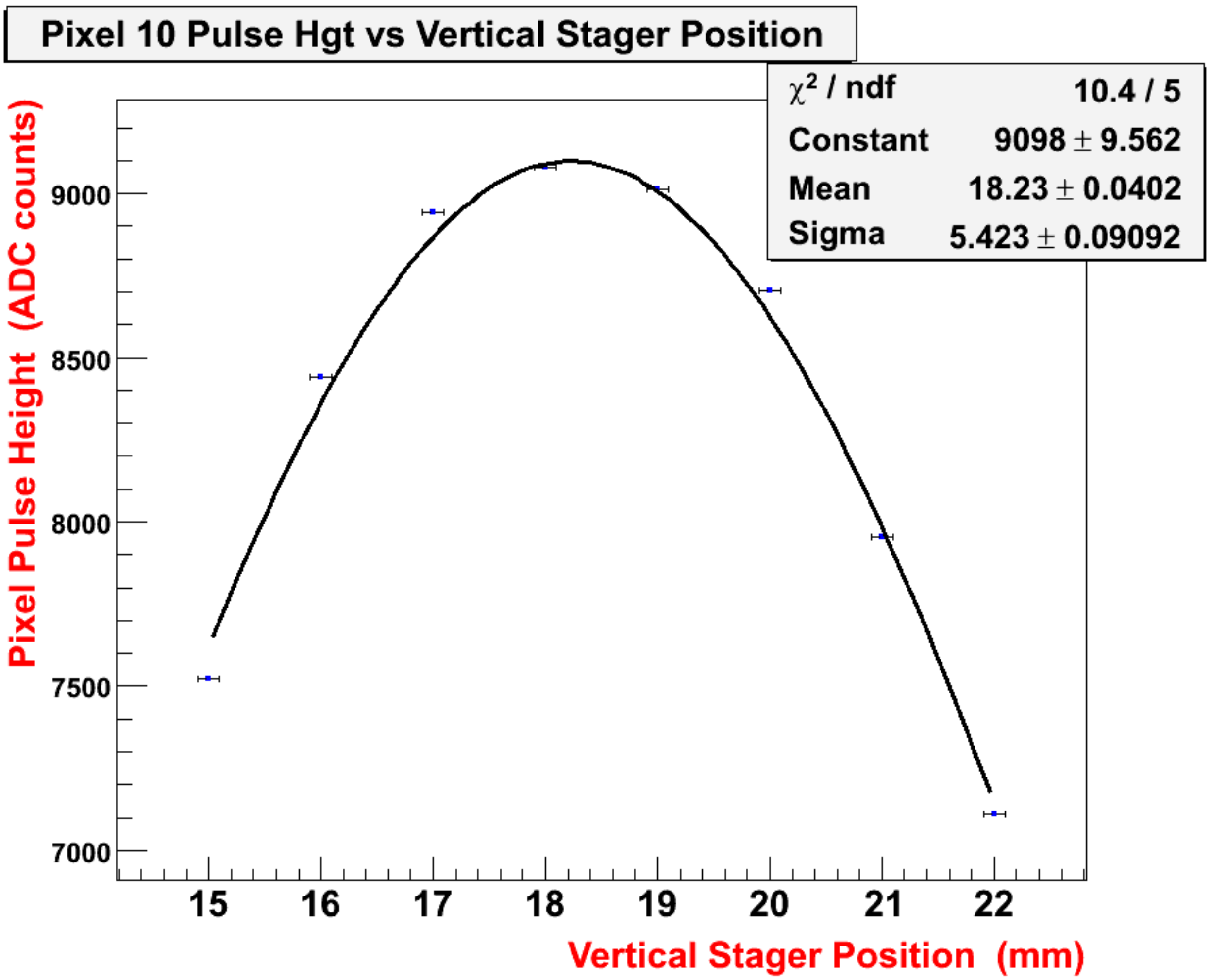

Figure 4. Vertical scan to determine the vertical center of pixel 10 of R8900 tube #NA0067. The mean of the Gaussian fit is considered to be the pixel center.

Gain Map NA0009 20060705 650V

P13 6.83 +/- 0.37 npe = 6.5+/- 0.4	P14 8.19 +/- 0.41 npe = 6.0+/- 0.3	P15 7.37 +/- 0.41 npe = 6.8+/- 0.4	P16 6.85 +/- 0.39 npe = 6.1+/- 0.4
P 9 7.20 +/- 0.40 npe = 5.5+/- 0.3	P10 6.22 +/- 0.39 npe = 5.4+/- 0.4	P11 6.04 +/- 0.31 npe = 5.4+/- 0.3	P12 8.38 +/- 0.46 npe = 5.5+/- 0.3
P 5 6.65 +/- 0.38 npe = 5.1+/- 0.3	P 6 5.35 +/- 0.30 npe = 6.0+/- 0.4	P 7 6.35 +/- 0.39 npe = 4.9+/- 0.3	P 8 7.69 +/- 0.46 npe = 5.8+/- 0.4
P 1 6.24 +/- 0.38 npe = 5.0+/- 0.3	P 2 7.10 +/- 0.39 npe = 6.0+/- 0.4	P 3 9.72 +/- 0.55 npe = 5.8+/- 0.4	P 4 9.53 +/- 0.51 npe = 5.5+/- 0.3

Gain in Units of 10^5

Figure 5. Gainmap of R8900 tube #NA0009. Pixel numbers are displayed in the top right corner of each box, gain in the center, and the number of photoelectrons at the bottom.

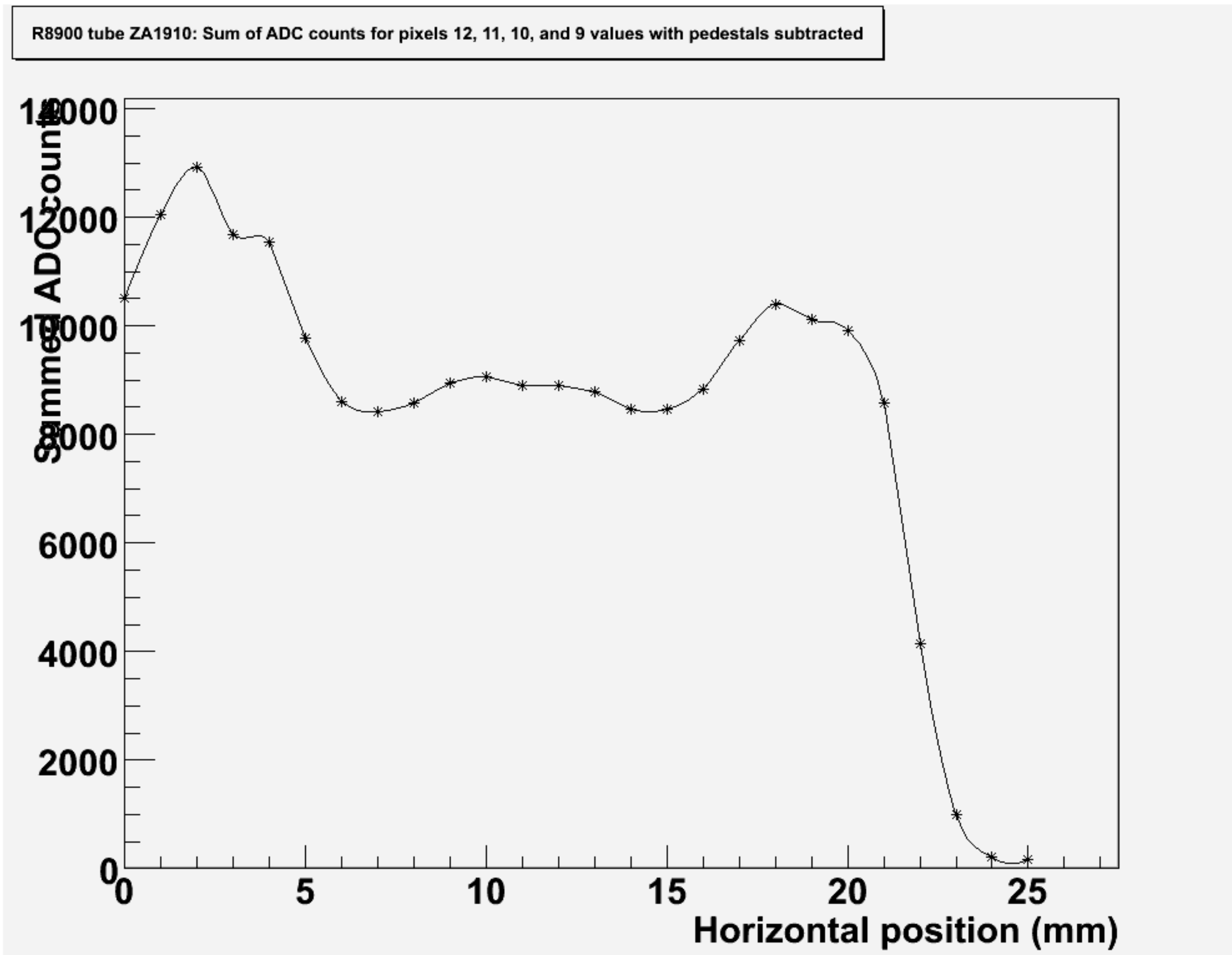

Figure 6. Horizontal scan results for R8900 tube #ZA1910. The edges of the tube are located near 0 mm and 24 mm in x.

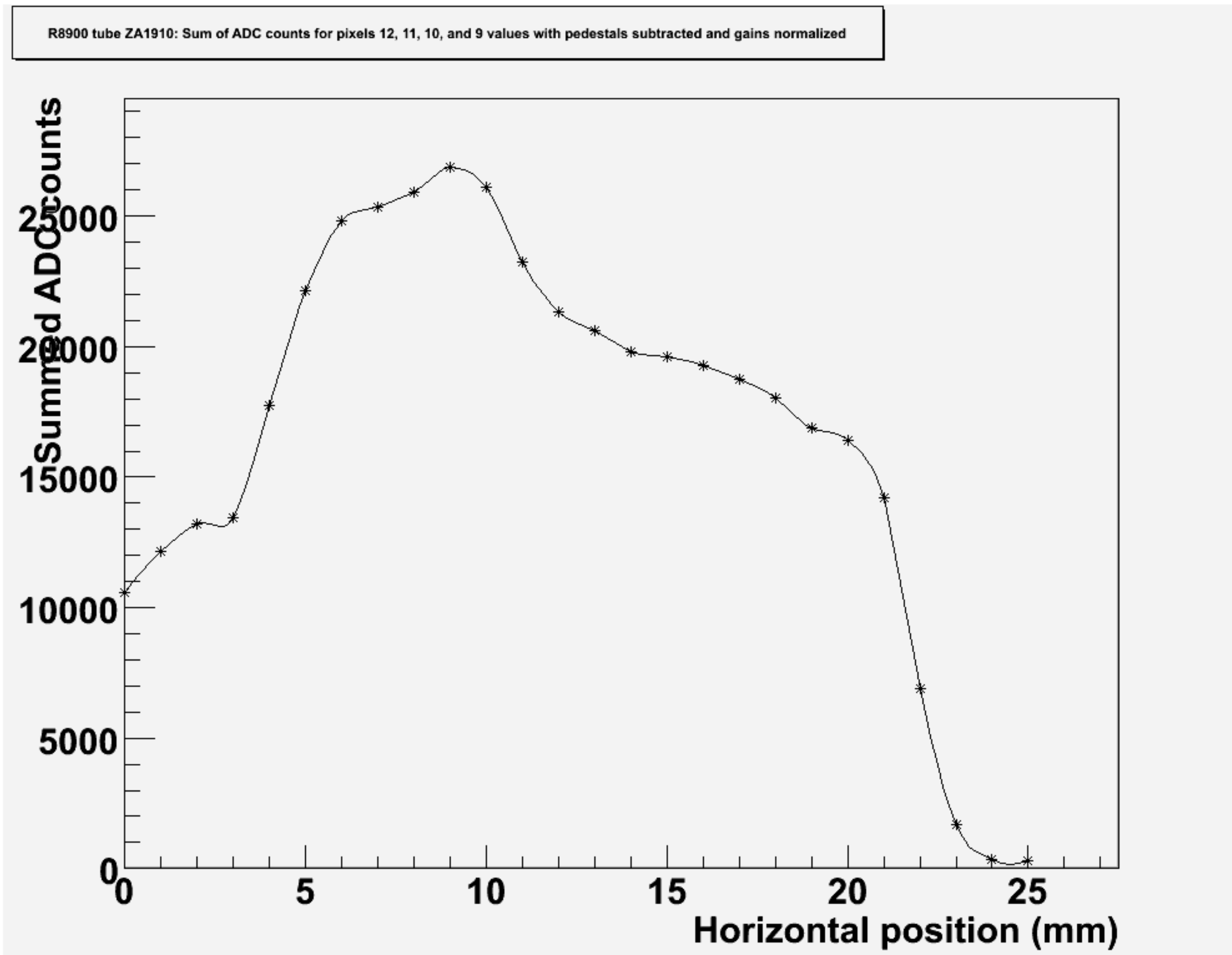

Figure 7. R8900 horizontal scan results with gain corrections.

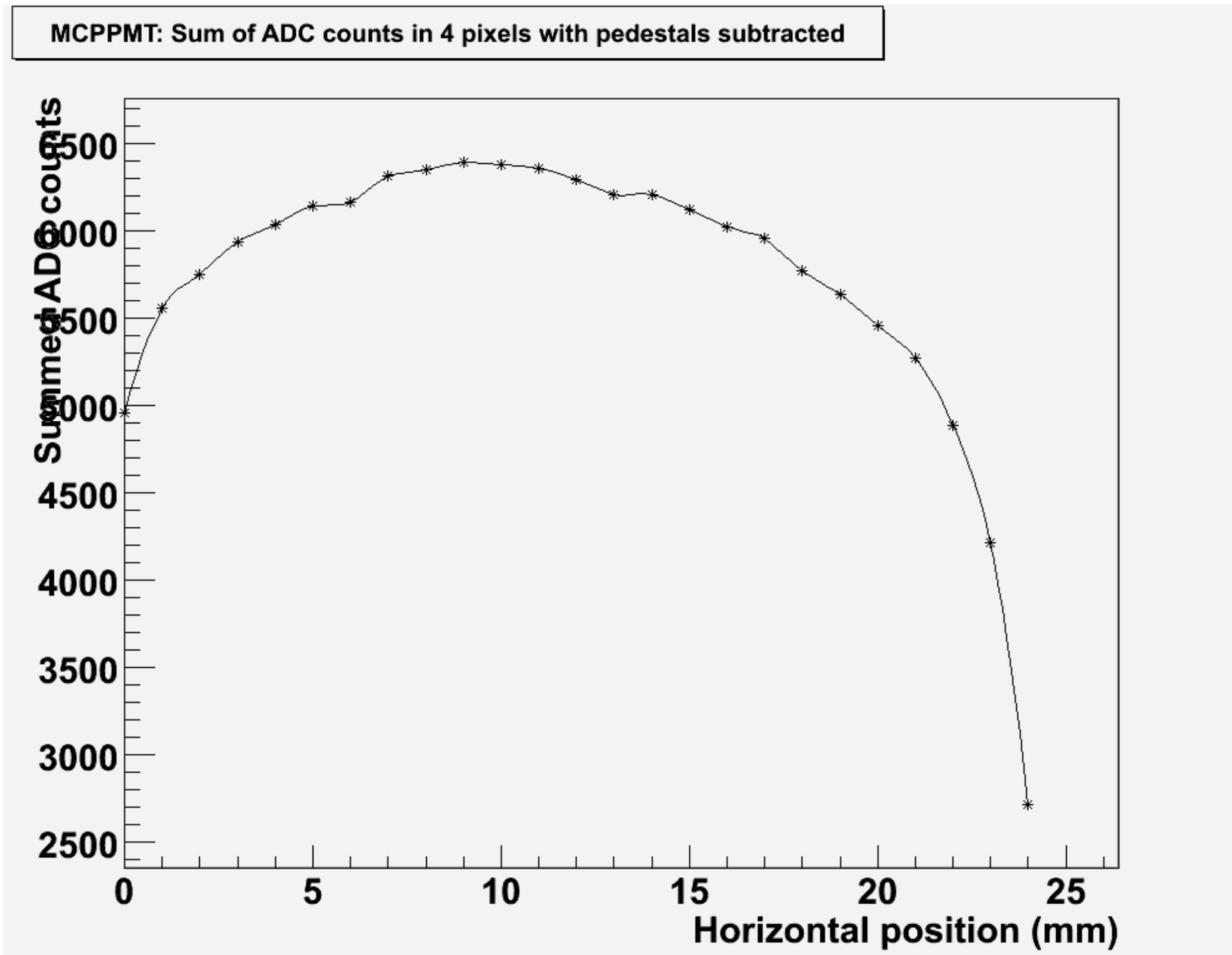

Figure 8. Horizontal scan results for the MCPPMT. The edge of the tube is located near 24 mm in x, and the center of the pixel and edge of the active quadrant is near 0 mm in x.

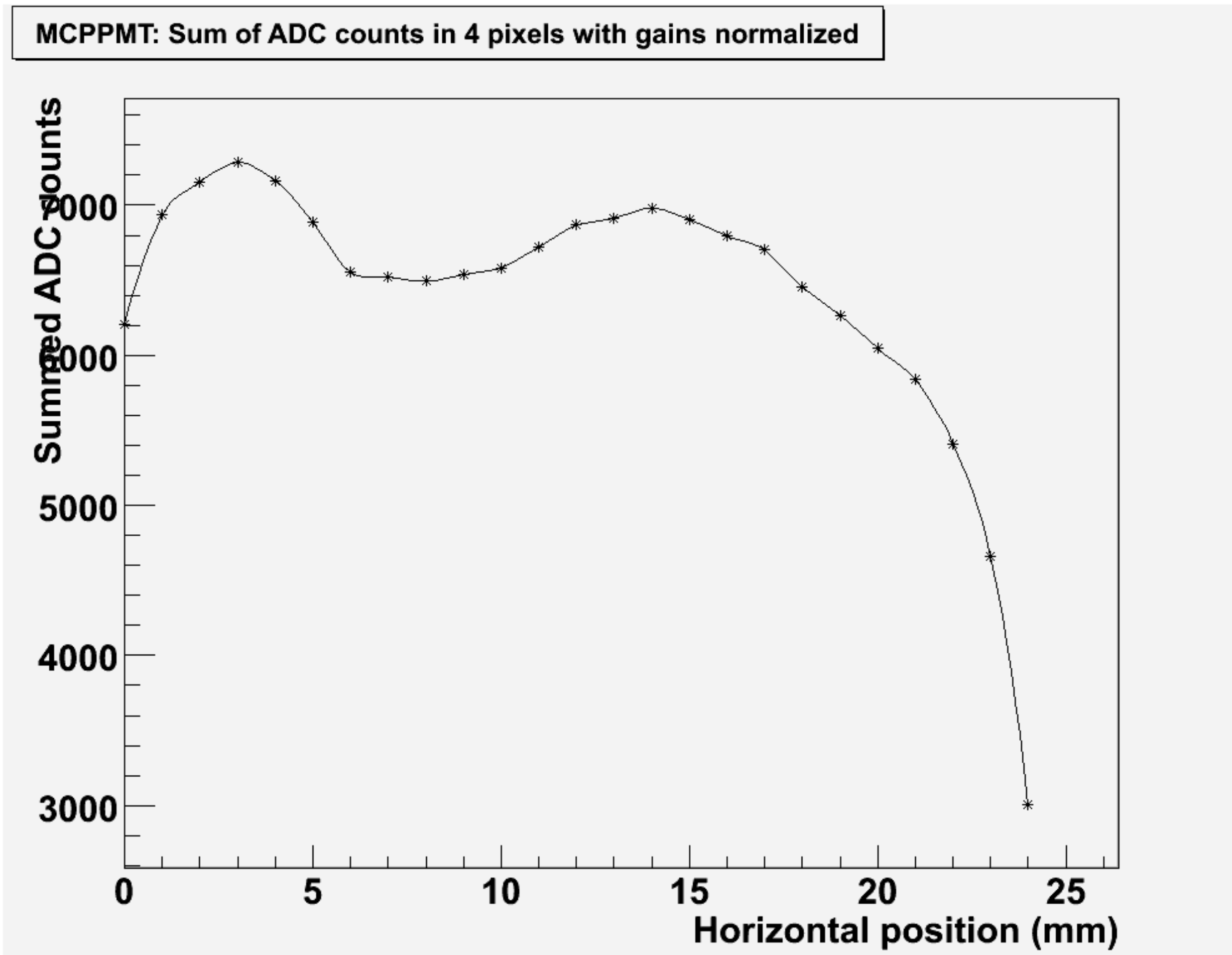

Figure 9. MCPPMT horizontal scan results with gain correction.